HYDROGEOLOGY OF THE SANTA CLARA AND COYOTE VALLEYS GROUNDWATER BASINS, CALIFORNIA

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ABSTRACT

Located in the central coast ranges of California, just inland from the coast, and south of San Francisco Bay, the Santa Clara Valley basin and its tributary basin, Coyote Valley, represents one of the significant alluvial tilled groundwater basins of California. One-half of the water used in the Santa Clara Valley and all those used in Coyote Valley are pumped from the basins. This presentation discusses the hydrogeologic make up of the basins and how it affects basin management.

The basins are filled by alluvial materials washed in from the adjoining foothills and mountainous watersheds. In Santa Clara Valley the massive alluvial deposits of the elevated edges of the basin and the stratified section that occur down the fans and in the basin interior have compartmented the basin into [illegible] hydrogeologic units. These are noted as the forebay or recharging area in the upper fan area, the upper aquifer zone, and the lower confined aquifer zone in the basin interior. Coyote Valley is essentially one 'unconfined unit analogous to the forebay of Santa Clara Valley.

Groundwater pumping started before the turn of the century and its development and later overdrafting of the basin have induced land subsidence caused by the declining pressures in the lower confined aquifer zone and to saltwater intrusion in the upper aquifer zone fronting San Francisco Bay. With the importation of water from state, federal, and City of San Francisco water projects starting in 1965, land subsidence ceased in 1969 and saltwater intrusion ceased to advance since about 1980. In Santa Clara Valley land use has changed from agricultural to urban, though Coyote Valley is still largely agricultural. This change in Santa Clara Valley presents threats to groundwater and surface water quality. This presentation will particularly focus upon how the groundwaters within the hydrogeologic make up of the basin would be affected by these threats that may potentially degrade groundwater quality.

INTRODUCTION

This presentation discusses physiographic, geologic, and hydrogeologic features of the groundwater basins that lie beneath Santa Clara Valley and Coyote Valley, and how these play a role in the management of the groundwater basins. It will particularly focus upon how groundwater within the hydrogeologic make up of the basin would be affected by threats to water quality by urbanization and industrial-ization. The study area is located in the central portion of California just inland from its west coastal area and south of San Francisco Bay in Santa Clara County. The northern County boundary lies 30 miles southeast of San Francisco. Santa Clara Valley occupies the north central portion of the County and is interconnected to Coyote Valley at its south-eastern end. Coyote Valley continues south-easterly where it is, in turn, 'connected to the Llagas Basin in' the south central portion of the County (Figure 1).

The purposes of this study are to describe the general physiographic, geologic and hydrogeologic features of the groundwater basin and to describe how these play a role in particular to the protection of groundwater quality. The discussion is general with references made to available previous reports of the area.

REGIONAL PHYSIOGRAPHIC FEATURES AND DRAINAGES

Santa Clara and Coyote Valleys represent the southern portion of a northwesterly trending linear intermountain structural depression in the central Coast Ranges of California. San Francisco Bay occupies the central portion of this structural depression which forms the northern geographic boundary of the Santa Clara Valley basin. The northern geographic boundary of the basin is 15 miles wide with its western edge continuing northerly as the San Mateo plains and baylands and its eastern edge continuing northerly as the Alameda plains and baylands. Progressing

in Sanginés, E.M., Andersen, D.W.. and Buising. A.B., eds., 1995, Recent Geologic Studies in the San Francisco Bay Area: Pacific section S.E.P.M., Vol. 76, p. 173-192.

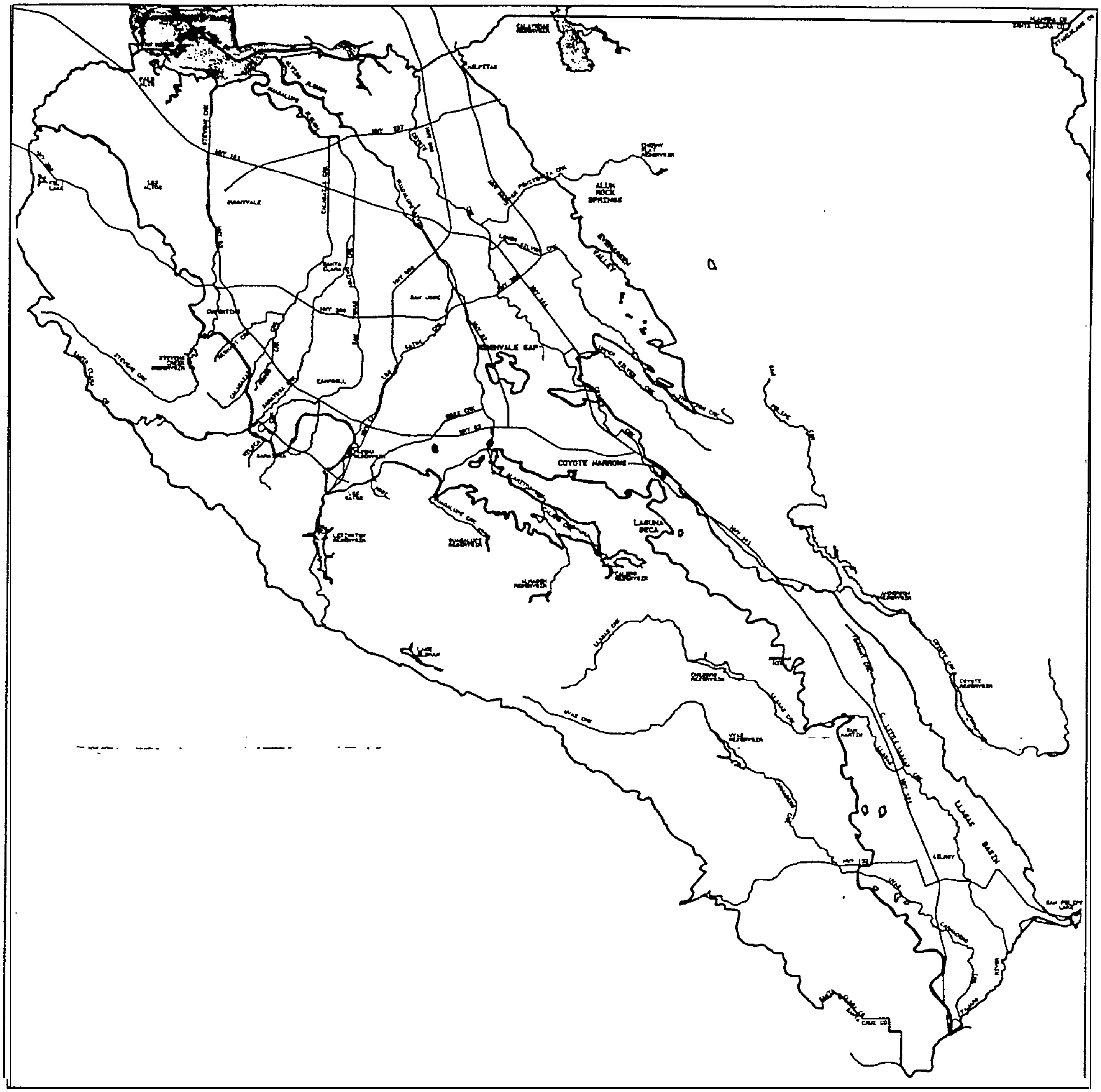


Figure 1. Location Map.

southerly, Santa Clara Valley narrows to about ½ mile at the Coyote Narrows located 25 miles southwest of San Francisco Bay. Coyote Valley, a narrow southeasterly trending valley, is connected to Santa Clara Valley at the Coyote Narrows and extends 7 miles to its interconnected boundary at Morgan Hill with the Llagas Basin. Coyote Valley widens to 3 miles at its southern boundary. The boundary is formed by a topographic divide of the Coyote Creek alluvial fan as it emerges from the eastern foothills.

Santa Clara and Coyote Valleys are laterally bounded by the Santa Cruz Mountains on the west and by the Diablo Range on the east.

Principal drainage is represented by Coyote Creek which originates in the Diablo Range, enters Coyote Valley at is southeastern end and flows northwesterly through Coyote Valley and Santa Clara Valley before entering San Francisco Bay. Other major drainages which pass through Santa Clara Valley include

Guadalupe River, Los Gatos Creek, San Tomas Creek, Saratoga Creek, Calabazas Creek, Stevens Creek, and Permanente Creek, all originating in the Santa Cruz Mountains. Drainages entering Santa Clara Valley from the western slope of the Diablo Range are smaller and the larger ones are represented by Penitencia Creek and Berryessa Creek.

The floor of Santa Clara Valley gently slopes from the elevated lateral and southern edges to the basin interior. The basin interior or baylands is at approximately sea level and is flat with imperceptible slope. Stream tributaries to the Bay had cut patterns of incised meanders on the flat baylands surface. Salt evaporator ponds are located adjacent to much of the southern San Francisco Bayfront and are confined by both inboard and outboard levee systems.

The floor of Coyote Valley slopes from the lateral edges of the Valley towards its axial trough which slopes gently northwesterly from the topographic divide at its southern end to the basin outlet at the Coyote Narrows. Just upstream and to the southwest of the Coyote Narrows occurs a 2 square mile flat playa area referred to as Laguna Seca. Fisher Creek which drains the western side of Coyote Valley drains into Laguna Seca before eventually overflowing into Coyote Creek just upstream of the Coyote Narrows. Laguna Seca has been reclaimed for agricultural use.

REGIONAL GEOLOGIC FEATURES

The northwesterly trending intermountain San Francisco Bay depression is a large structural trough created by a downwarping of the geologic features. Major northwesterly trending faults flank the structural trough and these include the San Andreas fault system in the Santa Cruz Mountains, the Hayward fault along the eastern edge of the trough, and the Calaveras fault in the Diablo Range. Other large northwesterly faults occur within the trough and mountainous areas.

Unconsolidated alluvial sediments have washed into this structural depression to substantial thicknesses from the flanking mountains and they constitute the floor of the valleys and San Francisco Bay. Faults occurring beneath and within the valley portions are largely concealed under the uppermost levels of the alluvial fill of the basins. Past differential movements of the faults within the basin have provided an irregular bedrock basement beneath the alluvial fill. The accumulation of alluvial fill within the valleys constitute the groundwater basins.

HYDROGEOLOGY OF SANTA CLARA VALLEY BASIN

Nonwater-Bearing and Water-Bearing Formations

For the purposes of groundwater studies, geologic formations are divided into nonwater-bearing and water-bearing formations. Nonwater-bearing are those that contain and transmit water only in small quantities and are denoted here in the study area as consolidated bedrock formations. They comprise the mountainous areas and form the basement boundaries of the basins.

Water-bearing formations are those that contain and transmit water in copious quantities. These formations are represented by the unconsolidated alluvial fill and the unconsolidated to lightly consolidated Santa Clara Formation. The latter formation is here considered to be in part water-bearing since where it occurs in the mountainous foothills it is essentially nonwater-bearing while it is water-bearing where it occurs in the valley areas beneath the alluvial fill.

The large aggregation of water-bearing formations constitutes a groundwater basin. Smaller aggregation of water-bearing materials represents small scale local groundwater basins or small mountain valley basins of usually very shallow depths.

Basis for Basin Boundary Delineation

The basin boundary is delineated along the edge of the valley fill at its contact with consolidated bedrock formations at the surface and beneath the fill. However, because the Santa Clara Formation is in part water-bearing, in places the division line occurs along the valley fill-Santa Clara Formation along the foothills line.

The Santa Clara Formation is an alluvially deposited formation washed down from the upper mountainous area and is now deposited along the foothills and beneath the unconsolidated young alluvial fill of the basin (Dibblee, 1964). This formation is Plio-Pleistocene (Bailey and Everhart, 1964). Where it occurs in the foothills, this formation consists predominantly of massively bedded silt and clay and clayey gravels, which are all lightly consolidated. After this formation dips beneath the young alluvial fill, it becomes better sorted and more stratified as to represent a section of interbedded sand, gravel, clayey gravel, silt and clay. Here these deposits are similar in water-bearing character to the overlying young alluvial fill. The subsurface contact between the Santa Clara

Formation and the young alluvial fill cannot be distinguished. Consequently, these will be discussed collectively as one alluvia! fill deposit for practical purposes.

Nonwater-Bearing Formations

Nonwater-bearing bedrock formations are older than 1 million years old, They contain and transmit water through variously spaced fracture and fault openings which usually become progressively smaller with depth. Astutely located wells drilled in these formations usually yield a few gallons per minute or less on a sustained basis, usually sufficient only for individual domestic needs (Iwamura, 1976). At great depths, nonwater-bearing marine sedimentary formations may contain salty waters.

As previously noted, the Santa Clara Formation where it occurs in the foothills is also classed as nonwater-bearing. These lightly consolidated, massively bedded alluvia! deposits contain very few aquifers; consequently wells drilled into this formation in the foothills yield little water on a sustained basis.

Water-Bearing Formations

Water-bearing formations consist of unconsolidated alluvia! fill materials washed in from the mountainous area. These deposits include the Holocene (0 to 10,000 years old) alluvial fill and the underlying similar and similarly deposited Santa Clara Formation.

The alluvia! fill section was deposited as granular alluvial fans of streams, as fine-grained basin deposits in the outer fan and interfan areas and as fine-grained shallow marine and tidal deposits during various stage levels of San Francisco Bay (Helley and Lajoie, 1979). The surficia! distribution of these deposits is shown on Figure 2. The maximum thickness of the alluvial fill in the basin is in excess of 1,500 feet (including the Santa Clara Formation) (California State Department of Water Resources, 1967).

From the elevated lateral and southern edges of the basin, gently sloping alluvial fans emerging from the basin's tributaries have laterally merged to form an alluvial apron, descending to the basin interior. Due to the mechanical sorting of alluvial sediments as they washed in from the mountains, coarse deposits represented by massive sections of permeable gravel and moderately to restrictively permeable "grave! and clay'' predominates in the upper fan areas along the elevated edges of the basin. Finer-grained but better sorted deposits are found further down the fan. Here strong stratification (layering) of cleaner, highly permeable sand and grave! with fine-grained and restrictively permeable to impermeable silt and clay beds become more prominent.

During the fan deposition process, previously deposited materials are cyclically washed farther down the fan and redeposited. This is usually caused by changes in the rate of deposition as influenced by changes in long-term climatic cycles. In most recent geologic past, the rate of deposition slowed, resulting in the entrenching of the stream courses onto the upper fan surfaces along the elevated edges of the basin and splaying of the redeposited materials in the outer fan areas as "younger fan deposits." The older fan and younger fan surfaces are delineated on Figure 2 on an approximate basis.

The outer fan surface merges with predominately fine-grained basin and marine deposits in the flat interior baylands area. Below the surface these deposits are highly stratified and have low permeability.

As ancient levels of the Bay fluctuated and the accumulation of shallow marine and basin deposits sagged in ancient times due to a consolidating process, the subsurface merging of the more permeable alluvial fan deposits and the lesser to essentially impermeable basin and marine deposits is one of complex interfingering and interlayering in nature. -Hence, the general subsurface section in the mid-lower fan areas and the basin interior, including the section beneath San Francisco Bay is dominated by a strongly stratified section of essentially impermeable silt and clay beds interbedded with sand and gravel beds. Many of the sands and grave! deposits within the interior basin section are represented by sinuous individual buried ancient stream channels with limited lateral continuity as these ancient streams etched their courses into the ancient marine and basin deposits surface.

The lower most section within the basin where it is deeper than 1,000 feet, usually contains a lesser number of sand and grave! layers.

Aquifer-Aquitard Systems, Occurrence and Recharge of Groundwater

The permeable coarse-grained beds and stream channel deposits represent aquifers while the restrictively permeable to essentially impermeable silt and clay beds represent aquitards. Well sorted sands and gravels are highly permeable and they represent excellent aquifers. What is termed massive "gravel and clay" of the upper alluvia! fan area represent aquifers of varying permeability from moderate to low.

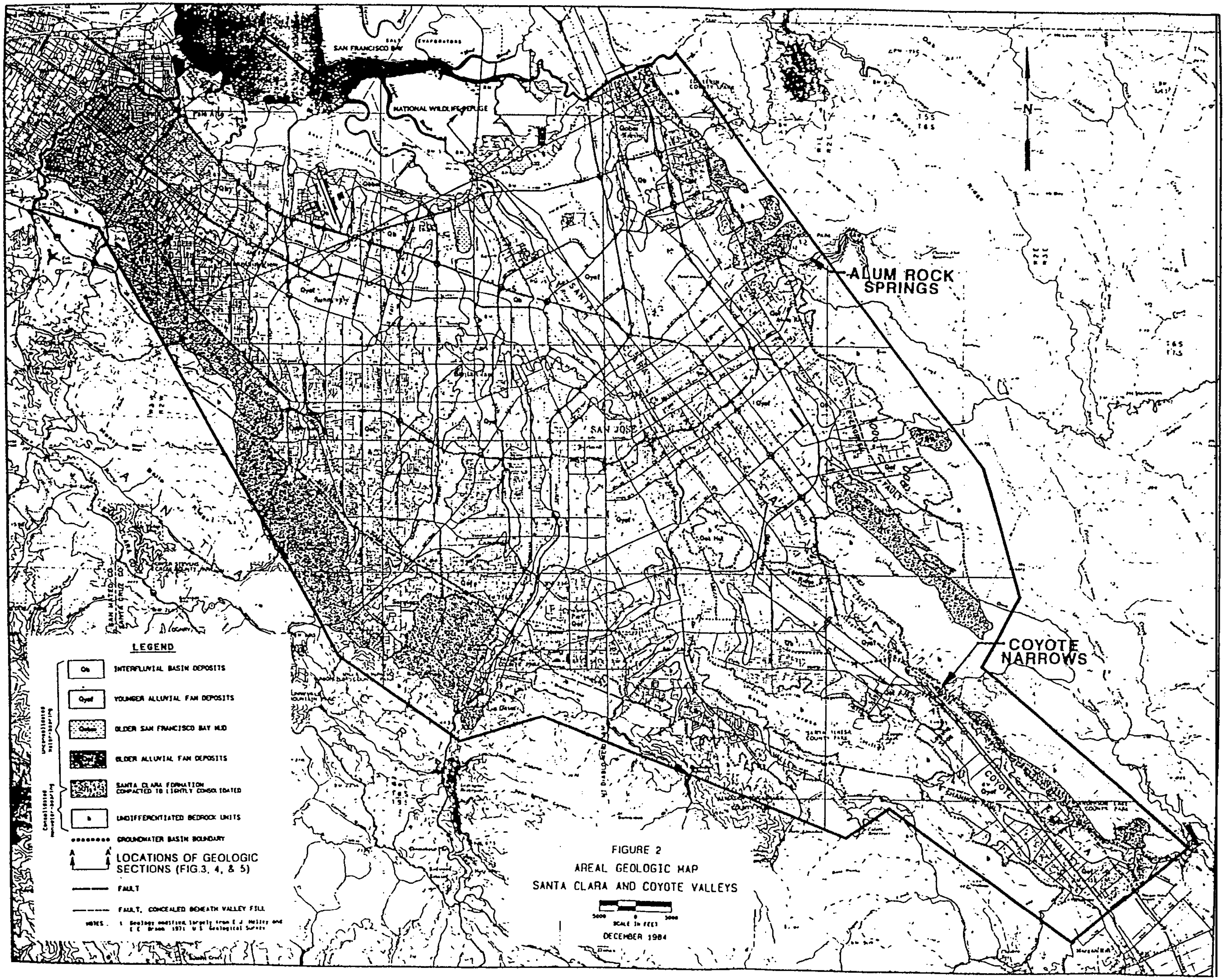

SAN FRANCISCO BAY
SALT EVAPORATORS
NATIONAL WILDLIFE REFUGE
N
ALUM ROCK SPRINGS
SAN JOSE
COYOTE NARROWS
COYOTE
LEGEND
Qb INTERFLUVIAL BASIN DEPOSITS
Qyaf YOUNGER ALLUVIAL FAN DEPOSITS
Qobm OLDER SAN FRANCISCO BAY MUD
Qoaf OLDER ALLUVIAL FAN DEPOSITS
QTsc SANTA CLARA FORMATION COMPACTED TO LIGHTLY CONSOLIDATED
b UNDIFFERENTIATED BEDROCK UNITS
Unconsolidated water-bearing
Consolidated nonwater-bearing
GROUNDWATER BASIN BOUNDARY
A A' LOCATIONS OF GEOLOGIC SECTIONS (FIG.3, 4, & 5)
FAULT
FAULT, CONCEALED BENEATH VALLEY FILL
NOTES. 1. Geology modified largely from E.J. Helley and E.E. Brabb 1971 U.S. Geological Survey
5000 0 5000
SCALE IN FEET

FIGURE 2
AREAL GEOLOGIC MAP
SANTA CLARA AND COYOTE VALLEYS

DECEMBER 1984

Aquifer materials predominate in the elevated upper alluvial fan areas and begin to decrease and become stratified with increasing clay and silt aquitards down the fan to the basin interior. Figures 3, 4, and 5 show the general aquifer-aquitard systems within the basin, as based upon available well logs.

For practical groundwater study purposes, the aquifers are grouped into the following hydrogeologic units: (1) forebay, (2) upper aquifer zone, and (3) lower aquifer zone. The approximate areal boundary as outlined by the forebay-confined line is shown on Figure 6 and in section view on Figure 5. The upper and lower aquifer zones occur within the confined boundary.

The forebay area occurs along the elevated edges of the basin in the upper alluvial fan areas. The forebay consists predominantly of aquifer materials with discontinuous or leaky aquitards. Here groundwater occurs unconfined, or under water table condition. Santa Clara Valley groundwater basin receives its principal recharge in the forebay by deep infiltration from streams, applied irrigation waters in excess of evapotranspiration, rainfall, and percolation ponds as part of the Santa Clara Valley Water District's (District) artificial recharge operation (California State Water Resources Board, 1955). Much smaller amounts are recharged as subsurface inflow from Coyote Valley through the Coyote Narrows and as hidden recharge from the nonwater-bearing formations that laterally bound the basin. At random locations above the water table within the forebay, perched groundwater occurs upon discontinuous aquitards on a permanent or temporary basis.

Within the interior portion of the basin the aquifers sloping from the forebay become distinctively divided into numerous separate aquifers within a predominantly clayey section. The "upper aquifer zone" is referred to aquifers that occur roughly within the upper 150 feet from the surface and the "lower aquifer zone" is referred to aquifers that occur at depths below 150 feet. The premise for this delineation is that all aquifers in the basin interior occurring beneath 150 feet are "confined" or in other words the groundwater occurs under pressure. The pressure is sustained through aquifer connection to the forebay where water table conditions occur at levels far above the confining aquitards. Recharge to the lower aquifer is through its lateral connections from the "common" forebay.

In the upper aquifer zone, groundwater occurs unconfined in the mid-lower fan area and under leaky confined condition in the basin interior that is capped by basin and shallow marine aquitard deposits. Groundwater in the deeper aquifers within the upper aquifer zone is also under leaky confinement (Jenks and Adamson, Inc., and Brown and Caldwell, Inc., 1974). The leakiness of the confining aquitards in the upper aquifer zone is attributable to either low compaction of the aquitard or discontinuities within the aquitards the aquifers due to depositional variations of materials. Recharge of the upper aquifer zone occurs laterally from interconnections with the forebay and/or from surface sources.

The two aquifer zones are separated by an extensive, thick compacted major aquitard that is essentially impermeable. This major aquitard is labeled on the geologic sections on Figures 3, 4, and 5. This aquitard feathers out in the upper fan area which governs the areal extent of the upper and lower aquifers from the common forebay. Similar essentially impermeable aquitards separate the individual aquifers of the lower aquifer zone. A generalized summary of the aquifer-aquitard systems and the various modes of groundwater occurrences is depicted on the diagrammatic geologic profile of the basin presented as Figure 7.

From a basin utility standpoint, at present most of the groundwater pumped from the basin is from the lower confined zone, followed by that pumped from the forebay. Aquifers of the upper zone are little used now, only serving uses for local domestic or agricultural purposes. There is no doubt that some of the deeper wells may be extracting water from both zones through multiple perforations.

Movement of Groundwater

As previously indicated, the principal recharge to the basin occurs by deep infiltration in the elevated lateral and southern forebays of the basin. From these elevated areas, the general movement of groundwater is down the gradient toward the interior portion of the basin where most of the groundwater is pumped. Groundwater gradients are locally modified in areas of heavy pumping. In the lower aquifer zone, there may occur a slight inland gradient from beneath San Francisco Bay in response to pumping along the bayfront area.

Effects of Faults

Several faults, including the Shannon fault and Evergreen fault (Figure 2), and suspected faults occur within the groundwater basin, concealed beneath the surficial alluvial fill deposits. It is suspected that these faults originating in the basement rocks offset the Santa Clara Formation and lower section of the young alluvial fill deposits but do not project to the surface. However, there is no evidence that faults have any effect upon the general flow of groundwater within the basin (California State Department of Water Resources, 1975). In other groundwater basins, faults form definite impeding features to the general flow of groundwaters.

DEVELOPMENT OF GROUNDWATER, WATER LEVEL FLUCTUATIONS, LAND SUBSIDENCE, AND SALTWATER INTRUSION

Significant pumping of the basin started around the turn of the century and continued to increase until 1965. Before development occurred in the basin, the basin was essentially full and surface streams that flowed across the unconfined or recharge areas, flowed as "rejected recharge," or flowed on a balance of recharge and natural discharges. In the early stages of groundwater development, wells drilled into the lower aquifer zone in the lower interior portion of the basin discharged naturally as flowing artesian wells. The area of flowing artesian and intermittently flowing artesian wells at 1920 conditions is shown on Figure 6 (Clark, 1917).

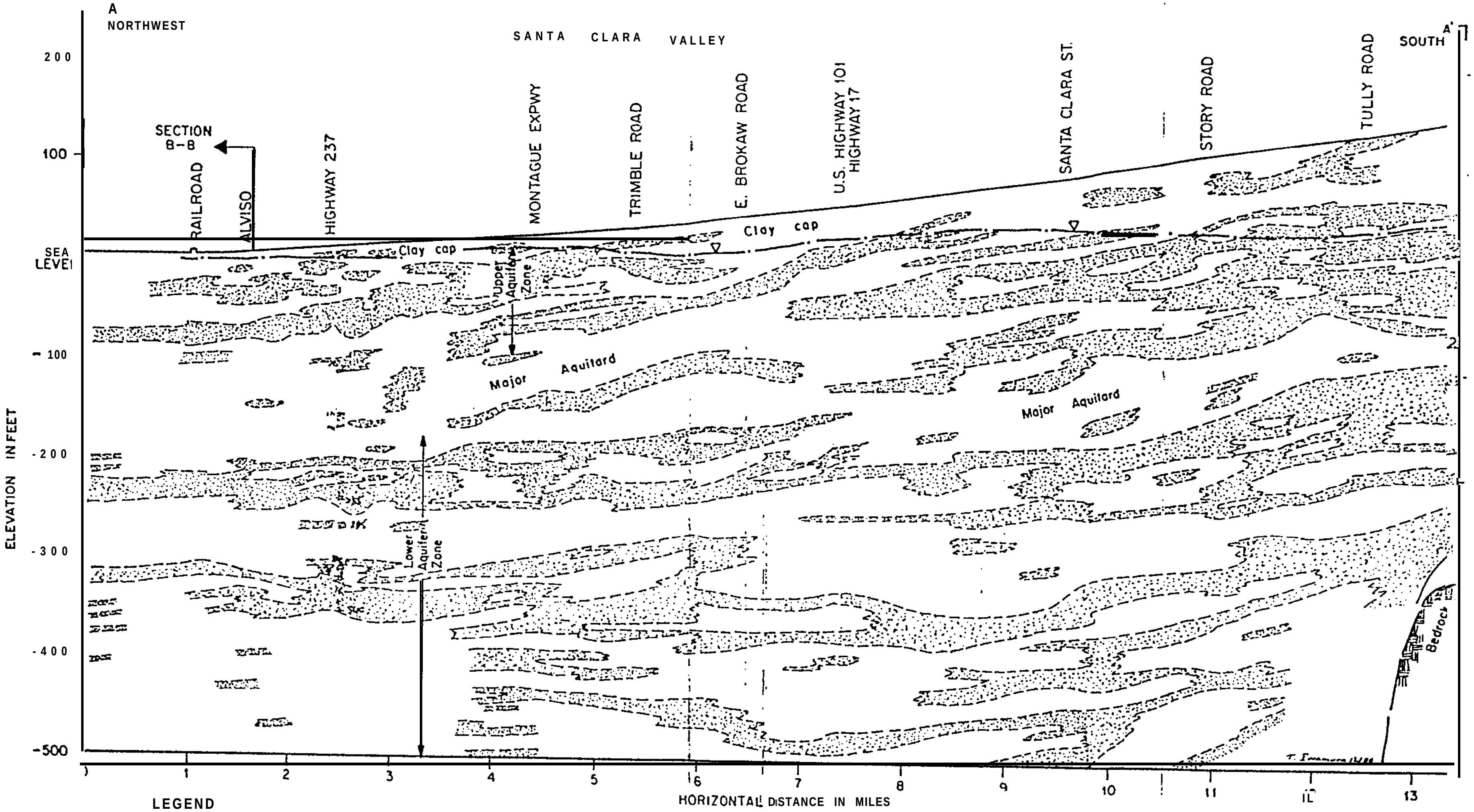
As groundwater production increased, eventually leading to a condition of overdraft, the water table began to decline steadily in the forebay and upper aquifer zone and the artesian flows from the lower aquifer ceased as pressures declined. The decrease in groundwater levels in the San Francisco Bayfront area caused a reversal in gradient in the upper aquifer zone which induced saltwater into the zone (Tolman and Poland, 1940).

As the pressures began to decline in the lower aquifer zone, the land surface in the interior portion of the basin began slowly to depress or subside (Tolman and Poland, 1940, and Poland, 1969). The bayfront had to be leveed as well as along the tributary stream banks to prevent inland encroachment of San Francisco Bay as lands fringing the Bay began to sink below sea level. This land subsidence along the Bayfront is largely responsible for the aggravation of saltwater intrusion by allowing tidal Bay waters to invade farther upstream along the tributary streams. Saltwater was then drawn through the leaky clay cap of the baylands deposits as pumping of the upper aquifer zone induced lower pressures (Iwamura, 1980). Saltwater intrusion continued on an intermittent basis until about 1980. The area that had become definitely intruded is depicted on Figure 6, representing essentially present conditions.

After the formation of the Santa Clara Valley Water Conservation District in 1928, the forerunner to the present District, and the construction of water conservation reservoirs in the mountainous watershed, leading to artificial recharge in the forebay, the groundwater levels and pressures began to rise in 1935. This rise continued until 1944. During this period of water levels recovery, land subsidence ceased temporarily from 1937 to 1948. After 1944, water levels again started to decline as increased pumping resulted in overdraft and subsidence resumed from 1948. The greatest amount of subsidence occurred in an area just southeast of San Jose and in the Mountain View area. Between 1934 and 1967, land subsidence in these areas amounted to about eight feet (Poland and Ireland, 1968). Figure 8 shows lines of equal subsidence from 1934 to 1967. Since subsidence started before 1934 and continued to 1969, it is suspected that the total amount is greater and attaining almost 13 feet in the San Jose area (Poland, 1969). Land subsidence manifests itself as a broad, imperceptible sagging of the land surface over a large area, decreasing in amounts from the centers of subsidence toward the edges of the areas overlying the confined lower aquifer zone and also decreasing beyond the southern Bay shore.

The same reduction of pressures in the lower aquifer zone that caused land subsidence also led to a mild amount of saltwater intrusion into this zone from the intruded portions of the upper aquifer zone. These affected areas are small local areas beneath the large affected areas of the upper zone. As the major separating aquitard is essentially impermeable and thick, the only way such an intrusion could have occurred was through water wells that are perforated in both upper and lower zones, through gravel packed wells or through deep wells whose casing deteriorated due to disrepair (Iwamura, 1980).

Overdraft ceased in 1965 with the importation of waters from the State Water Project and City of San Francisco's Hetch Hetchy system. Land subsidence ceased in 1969 as pressures in the lower aquifer zone started to recover. In most recent years, pressures in the lower aquifer zone have recovered to the extent that wells within the basin interior again became flowing artesian on an intermittent seasonal basis. However, water levels within the forebay and in certain large pumping areas within the basin have not recovered to their pre-overdraft levels.



LEGEND

▨ DISTINGUISHABLE AQUIFERS--MIXTURES OF GRAVEL AND SAND. MEDIUM TO VERY HIGH PERMEABILITIES.

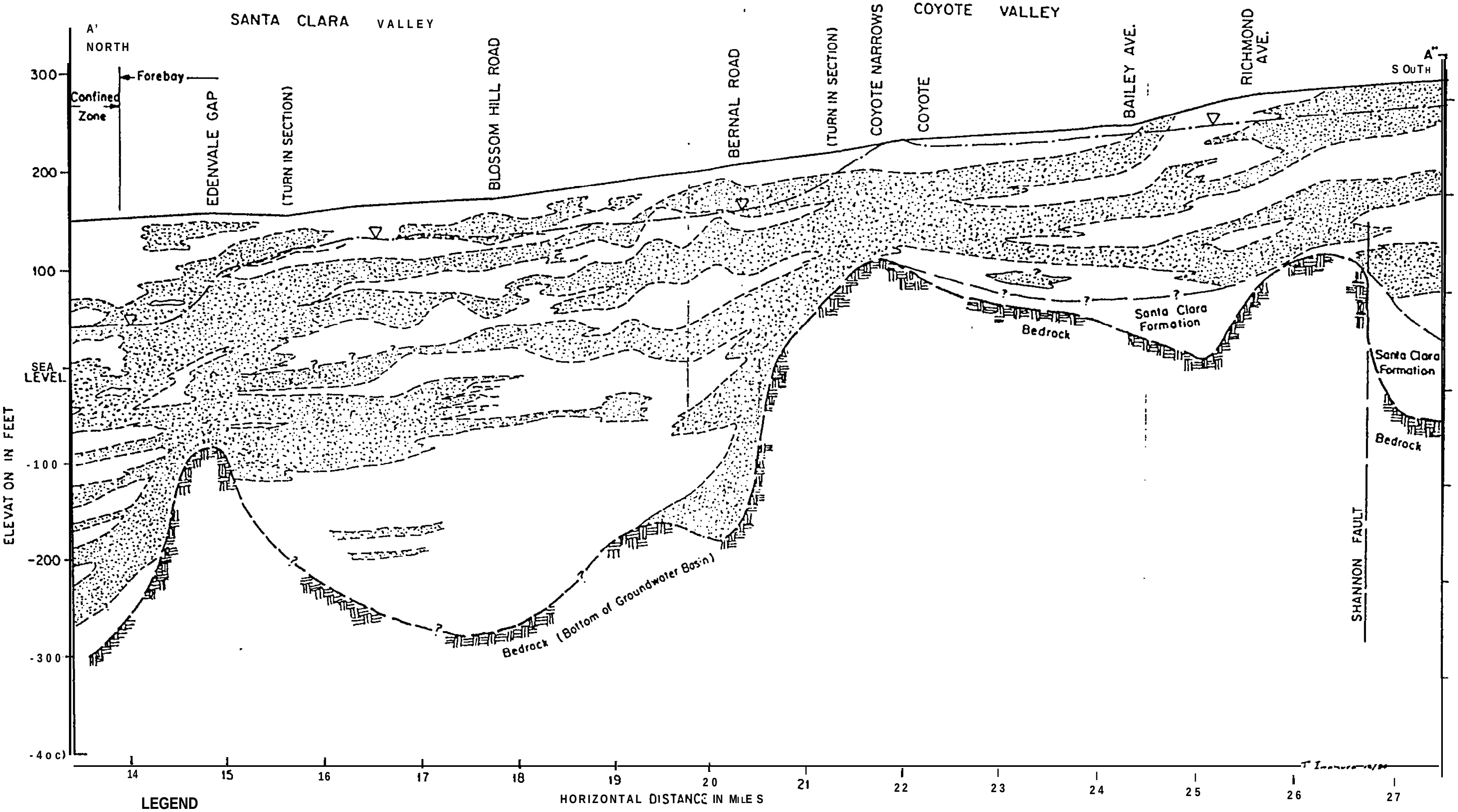
☐ AQUITARD--MIXTURES OF CLAY AND SILT, WITH SOME SAND AND GRAVEL, LOW TO VERY LOW PERMEABILITIES

—▽— APPROXIMATE WATER TABLE, 1984

FIGURE 3- INTERPRETIVE GEOLOGIC SECTION, A-A'
SANTA CLARA VALLEY

NOTES:

1. REFER TO FIGURE 2 FOR LOCATION OF SECTION.
2. INTERPRETIVE SECTION BASED UPON AVAILABLE WELL LOGS.
3. AQUIFERS ARE GROUPED INTO UPPER AQUIFER ZONE AND LOWER AQUIFER ZONE, SEPARATED BY "MAJOR" AQUITARD.



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1. REFER TO FIGURE 2 FOR LOCATION OF SECTION.
2. INTERPRETIVE SECTION BASED UPON AVAILABLE WELL LOGS.
3. MOST OF SECTION A'-A" IS FOREBAY ZONE, TO JUST PAST EDENVALE GAP.

FIGURE 4- INTERPRETIVE GEOLOGIC SECTION, A'-A"
PORTIONS OF SANTA CLARA AND COYOTE VALLEYS

Figure 9 graphically summarizes the approximate average water levels of the basin between 1908 and 1993 and the rate of cumulative maximum subsidence from 1910 to 1969. It also shows estimated cumulative growth of population in the basin and annual rainfall from 1908 to 1993.

HYDROGEOLOGY OF COYOTE VALLEY BASIN

Water-Bearing Formations

The Coyote Valley Basin, whose lateral boundary is delineated on the same premise as Santa Clara Valley Basin, is laterally bounded by the Santa Clara Formation along its eastern side and by bedrock of the Santa Cruz Mountains on its western side. The water-bearing portion of the Santa Clara Formation that underlies the young alluvial fill of the basin along the lateral east and axial central portion of the basin will be discussed with the young alluvial fill as one water-bearing unit. Subsurface distinction cannot be made.

The bulk of the water-bearing alluvial fill deposits emanated from Coyote Creek as it enters the valley floor from the eastside Diablo Range at the southern topographic divide boundary with the Llagas Basin. These alluvial deposits splay out onto the floor of Coyote Valley and the Llagas Basin as the stream course 'in the geologic past fluctuated alternately to the north and south. Lesser amounts of alluvial materials were deposited by small west side tributaries from the Santa Cruz Mountains. As such, the topographic profile normal to the longitudinal axis of the Valley is asymmetrical with the alluvial fill higher along the east side and the axial trough of the Valley shifted to the west of center. The course of Coyote Creek flows along the elevated eastern edge of the Valley and a smaller stream, Fisher Creek, flows down the axial trough.

The maximum thickness of the alluvial fill materials, including the underlying Santa Clara Formation aggregates to about 500 feet at the southern topographic divide and grades to about 150 feet at its northern connection at the Coyote Narrows (California Department of Water Resources, 1981). The underlying basement, however, slopes gently but irregularly to the south and attains substantial depth beneath the southern portion of the Llagas Basin.

The alluvial fill consists predominantly of coarse-grained materials that constitute aquifers with lesser interbeds of clayey and silty aquitards. The distal toe of the Coyote Creek alluvial fan at the northern end of Coyote Valley, just southwest of the Coyote Narrows, is capped by a clayey surface. These were deposited as basin deposits at the Laguna Seca area (Figures 1 and 2).

Occurrence, Movement and Recharge of Groundwater

Groundwater occurs in the alluvial fill essentially unconfined and moves in a general northwesterly direction down the Valley. Under natural conditions, before the installation of an artificial drain system in the Laguna Seca area, part of the subsurface flow would discharge to the surface at Laguna Seca, creating a swampy condition as it overflowed into Coyote Creek. Even today, along Coyote Creek as it approaches the Coyote Narrows, groundwater rises and discharges into the channel. These discharges are caused by the narrowing width to ½ mile and the rising of the basement rock at the Coyote Narrows. As groundwater flows converge toward the restriction, they naturally begin to rise to the surface.

Due to the moderate to high permeability of the water-bearing alluvial fill, water levels are quite responsive to the runoffs of streams. Deep percolation of runoff along Coyote Creek represents the principal recharge to the basin with additional amounts from other smaller tributaries; irrigation returns, rainfall and as subsurface inflows from the nonwater-bearing formations along the lateral edges of the basin. Groundwater is transferred into the Santa Clara Valley basin as subsurface flow beneath the Coyote Narrows.

Effects of Faults

The northwesterly trending Shannon Fault cuts obliquely through Coyote Valley from the eastern foothills, passing beneath Laguna Seca, and then through the bedrock of the Santa Teresa Hills of the Santa Cruz Mountains before continuing northwesterly through the western edge of Santa Clara Valley (Figure 2). It is not known if the water-bearing alluvial fill of Coyote Valley is offset by this fault. There is no evidence that the flow of groundwater is affected by its presence.

If any other faults cut Coyote Valley, their locations and characters could only be speculated.

Development of Groundwater and Water Level Fluctuations

Before groundwater development occurred in the basin, the basin was essentially full, operating under a balanced condition of recharge at its upper end and naturally discharging at its northern end upstream of the Coyote Narrows.

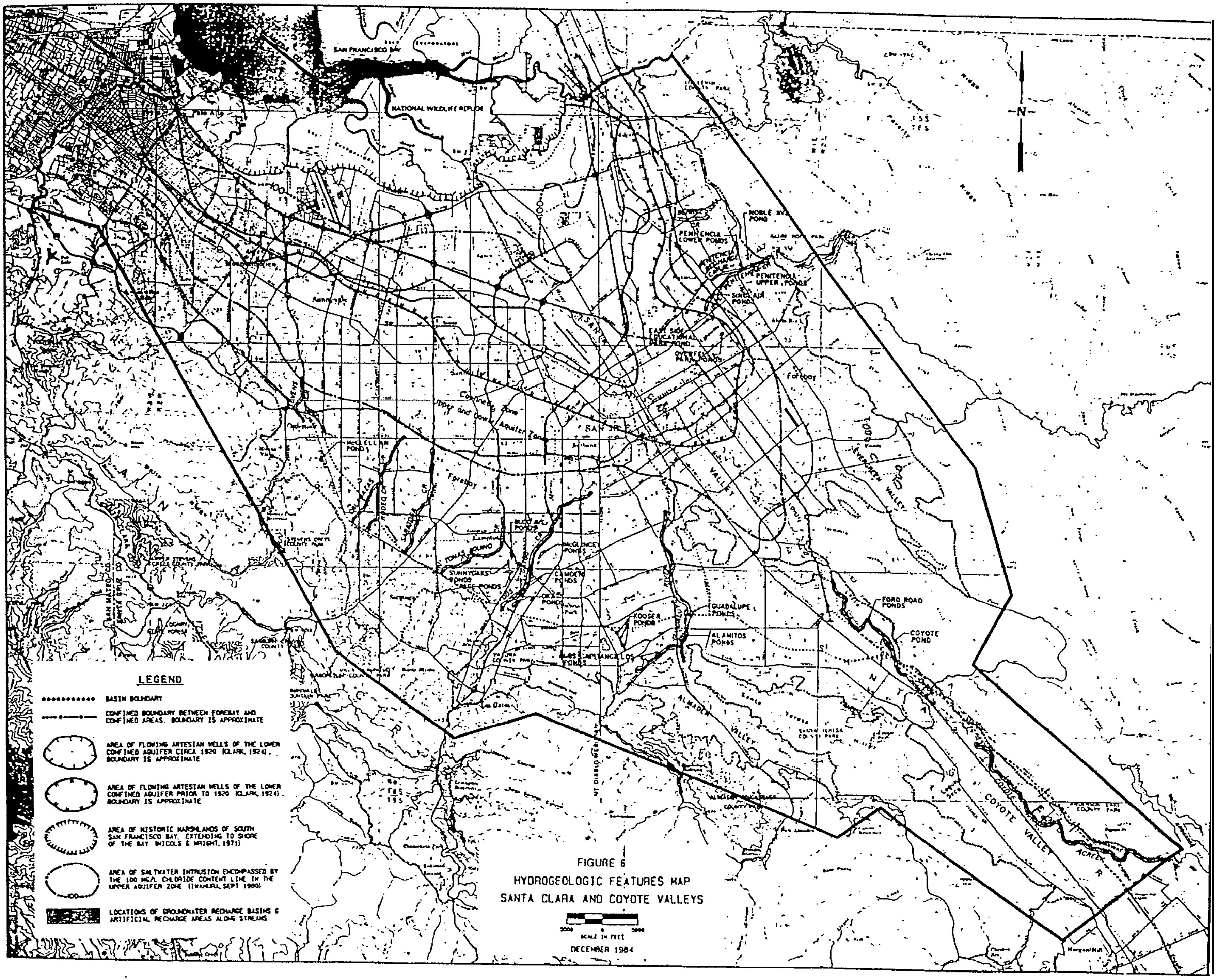
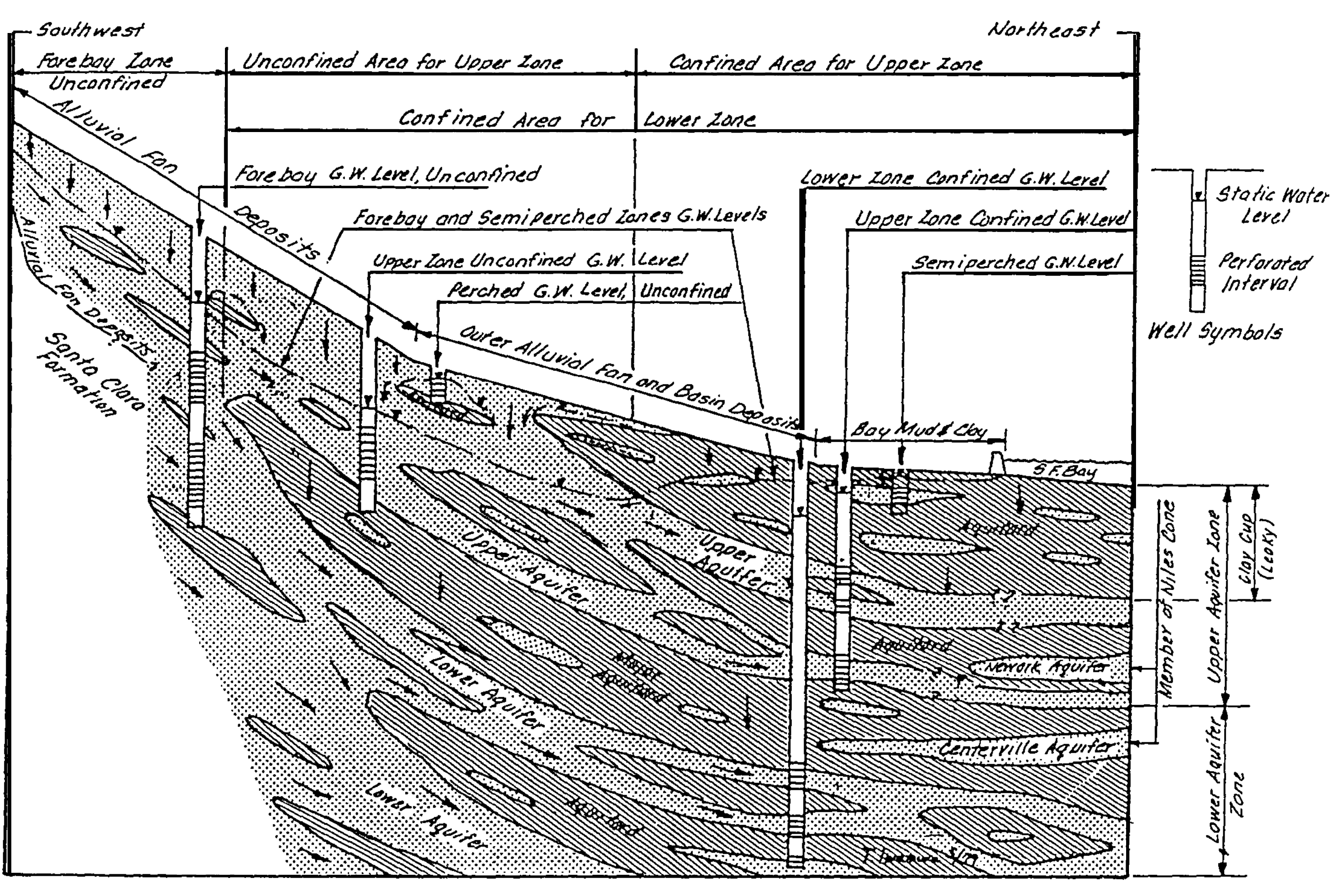

SAN FRANCISCO BAY
NATIONAL WILDLIFE REFUGE
N
NOBLE AVE POND
PENITENCIA LOWER PONDS
PENITENCIA CREEK
PENITENCIA UPPER PONDS
SINCLAIR POND
EAST SIDE EDUCATIONAL PARK POND
OVERFELT PARK POND
Forebay
Confined Zone
Upper and Lower Aquifer Zones
SAN JOSE
McCLELLAN POND
Forebay
BUDD AVE PONDS
McGLINCEY PONDS
SUNNYOAKS PONDS
PAGE PONDS
CAMDEN PONDS
OKA PONDS
KOOSER PONDS
GUADALUPE PONDS
ALAMITOS PONDS
FORD ROAD PONDS
COYOTE POND
SANTA CLARA VALLEY
EVERGREEN VALLEY
ALMADEN VALLEY
COYOTE VALLEY
COYOTE CREEK
SAN MATEO CO.
SANTA CRUZ CO.
Morgan Hill
LEGEND
BASIN BOUNDARY
CONFINED BOUNDARY BETWEEN FOREBAY AND CONFINED AREAS. BOUNDARY IS APPROXIMATE
AREA OF FLOWING ARTESIAN WELLS OF THE LOWER CONFINED AQUIFER CIRCA 1920 (CLARK, 1924). BOUNDARY IS APPROXIMATE
AREA OF FLOWING ARTESIAN WELLS OF THE LOWER CONFINED AQUIFER PRIOR TO 1920 (CLARK, 1924). BOUNDARY IS APPROXIMATE
AREA OF HISTORIC MARSHLANDS OF SOUTH SAN FRANCISCO BAY, EXTENDING TO SHORE OF THE BAY (NICOLS & WRIGHT, 1971)
AREA OF SALTWATER INTRUSION ENCOMPASSED BY THE 100 MG/L CHLORIDE CONTENT LINE IN THE UPPER AQUIFER ZONE (IWAMURA, SEPT 1980)
100
LOCATIONS OF GROUNDWATER RECHARGE BASINS & ARTIFICIAL RECHARGE AREAS ALONG STREAMS
5000
0
5000
SCALE IN FEET

FIGURE 6
HYDROGEOLOGIC FEATURES MAP
SANTA CLARA AND COYOTE VALLEYS

DECEMBER 1984



NOTES: 1. Arrows indicate direction of groundwater movement without regard to quantity.
2. Grossly exaggerated vertical scale.
3. From Iwamura, 1980

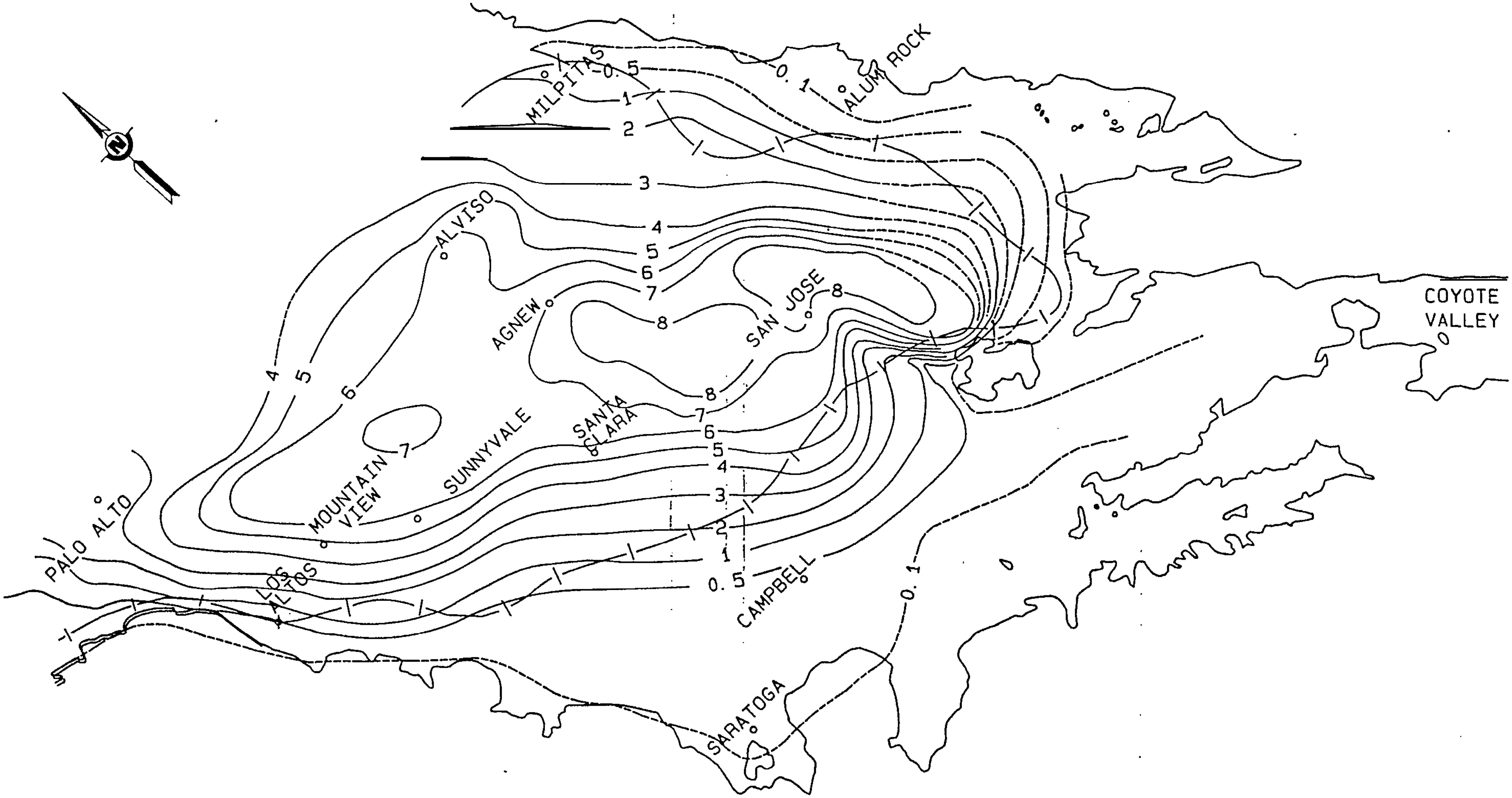
Figure 7. Diagramatic Geologic Profile Depicting Modes of Occurrance of Groundwater; Palo Alto - Mountain View Area.

After the start of significant development of groundwater in the early 1900's, water levels in much of the basin began to decline but then stabilized as pumping to date has not created a condition of overdraft. The initial lowering was in response to pumping and then stabilizing to equilibrium on annual operating levels basis. Water levels in the Laguna Seca area continue to occur at shallow depths and discharges continue to occur into the Coyote Creek channel upstream of the Coyote Narrows.

Coyote Reservoir, a water conservation project on Coyote Creek in the Diablo Range, was completed in 1936. As part of this project, the Coyote Canal was constructed through the foothills east of Coyote Valley to carry waters to be recharged in Santa Clara Valley. This Canal was constructed purposely to bypass the flows to avoid Coyote Valley on a year round basis so as not to aggravate the shallow groundwater drainage condition at Laguna Seca which has been reclaimed for agriculture.

Anderson Reservoir, also a water conservation project located downstream of Coyote Reservoir, was completed in 1950. Except for the passing of flood flows, flows through Coyote Valley were regulated in conjunction with diversions to the Coyote Canal. When the water levels at Laguna Seca rose to within 5 feet of the surface, recharge was pulled back along Coyote Creek as to limit the artificial recharge to the basin.

At this time, it is suspected that much greater amounts of groundwater pumpage can occur from the



1st ENTERED INTO CADD

1/91
1. CONTOUR LINE INTERVALS ARE IN FEET.
2. LOCATION OF SUBSIDENCE LINES IS APPROXIMATE
3 FROM POLAND, J F and GREEN J H., 1962. "SUBSIDENCE IN THE SANTA CLARA VALLEY, CALIFORNIA, A PROGRESS REPORT. "U S GEOLOGIC SURVEY WATER-SUPPLY PAPAER 1619-C

—|—|— CONFINED BOUNDARY BETWEEN FOREBAY AND CONFINED AREAS BOUNDARY IS APPROXIMATE

FIGURE 8
LINES OF EQUAL SUBSIDENCE
SANTA CLARA VALLEY
NORTH COUNTY
1934-1967

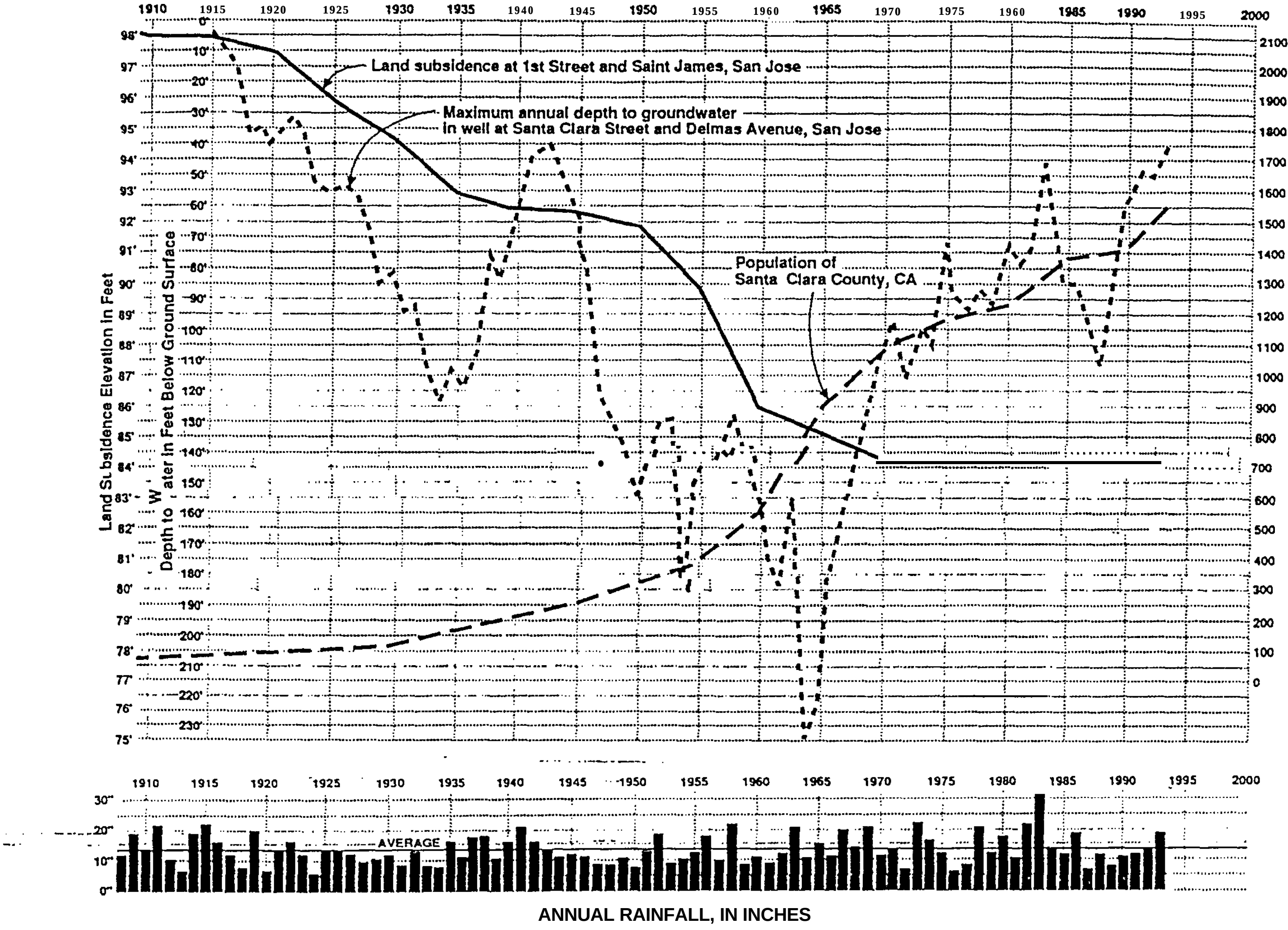


Figure 9. Rainfall, Average Depth to Water, Land Subsidence, and Population; Santa Clara Valley Groundwater Basin.

basin, if needed, without causing an overdraft condition. The increase can be supported by augmenting the recharge through regulating reservoir discharges and canal diversions.

GENERAL GROUNDWATER QUALITY

The general groundwater character of Santa Clara and Coyote Valleys is of excellent quality, suitable for most beneficial uses. Groundwater quality problems are confined to local areas within the basins, which could be attributed to natural conditions, basin operation upon development of groundwater, to other man-made conditions or to combinations of the foregoing conditions.

Mineral Character of Groundwater

Mineral characters of groundwater are a reflection of the characters of recharging surface waters and how these waters become altered as they infiltrate into the basin and percolate through the water-bearing formations. As recharging waters infiltrate and percolate through the formations, their mineral character changes through geochemical processes (interaction with formation materials). Usually more mineral salts become dissolved into them, as well as some other changes.

Groundwaters in Santa Clara and Coyote Valleys range in total dissolved salts content from 200 to

500 mg/l with somewhat numerous exceptions. Calcium carbonate hardness can be considered to be from hard to very hard. Most groundwater in Coyote Valley and in the upper and mid-fan area in Santa Clara Valley are a calcium-magnesium bicarbonate type or magnesium-calcium bicarbonate type. In Santa Clara Valley, as groundwater percolates farther down the fans to the baylands, the ratio of reacting values of sodium to the total cations in solution increases due to cation, or base, exchange with formation clays. Thus, farther down the fans groundwater usually changes to a mixed-cation bicarbonate type and eventually to a sodium bicarbonate type in the baylands (Iwamura, 1980). Base exchange is usually more prominent in the lower aquifer zones than in the upper aquifer zone.

In some areas of the Santa Clara Valley Basin, particularly in the baylands where the level of groundwater is near the ground surface, the uppermost groundwater may be naturally degraded by leaching waters from the surface and evaporating due to capillary action. These are degraded by an increase in mineral salts content.

Water Quality Problems

Saltwater intrusion in the upper aquifer zone fronting San Francisco Bay resulted from groundwater pumping and was aggravated by land subsidence. The area affected by definite saltwater intrusion as delineated by the 100 mg/l line of equal chloride content in the upper aquifer zone is shown on Figure 6. It should be noted that a chloride content of 100 mg/l does not limit the water use for all beneficial uses (Revelle, 1944). The indigenous unintruded groundwaters of the basin contain far less than 50 mg/l of chloride content.

It was noted that the 5,000 mg/l chloride content line in the upper zone fringes the inland side of the salt evaporator ponds along the southern edges of the Bay. Progressing inland, the chloride content drops off rapidly as saline water mixes with fresh groundwaters. The farthest inland intrusion in the upper zone occurs along Guadalupe Creek, along the axial trough of the Valley. Monitoring data indicate the present status of intrusion to be static.

Saltwater intrusion of the lower aquifer zone occurs in much smaller isolated areas in the bayfront area. These are low levels of intrusion that have occurred through interaquifer transfer through water wells. Monitoring data of the lower zone indicate the saltwater intrusion to be diminishing gradually at present.

The lower aquifer zone beneath San Francisco Bay was earlier noted to be unintruded (California State Department of Water Resources, 1960). Its present status is unknown as wells constructed there have been destroyed.

In an area near the mouth of Evergreen Valley in the southeastern part of Santa Clara Valley occurs connate water in aquifers deeper than 300 feet. Connate water is highly mineralized entrapped water that is indigenous to marine formations. These may have risen into the basin from underlying basement bedrock formations.

The area affected is bounded by Tully Road on the north, White Road on the east, the foothills to the south and U. S. Highway 101 on the west. This area is designated as Water Quality Zone 3 in the District's well standards ordinance, Ordinance 90-1 (Wilson and Iwamura, 1989). Some deep wells in the area had yielded waters containing over 1,500 mg/l chloride content. It is suspected that these affected waters are confined under pressure.

An area along Penitencia Creek alluvial fan extending to the Baylands contains groundwater with an anomalous boron content ranging up to several mg/l. It is suspected that the origin of boron is from Alum Rock mineral springs in the Diablo Range foothills, volcanic formations in the Alum Rock area, or from rising mineralized water along the Hayward or related faults.

Groundwater normally does not contain nitrate except in minute amounts. Anomalously high nitrate contents have been noted in local areas within both Santa Clara Valley and Coyote Valley (also in the Llagas Basin). Where these areas occur, nitrate contents in excess of 45 mg/l have been noted in numerous instances.

In North Santa Clara Valley, high nitrate contents have been noted in wells within the agricultural baylands area. In the Coyote Valley, the high nitrate content areas are along the west side of the Valley. The source of nitrate is from the application of fertilizers in agricultural practices and, in some instances, from septic tanks. Nitrate contents in Coyote Valley and Liagas Basin appear to be rising.

In Coyote Valley, the highest nitrate concentrations are located along the west side where the movement of groundwater is very slow and farthest away laterally from Coyote Creek, the source of principal recharge. The nitrates applied near the active recharge area in Coyote Valley are being displaced and diluted more rapidly than on the west side, as recharging waters do not contain nitrate.

Incidences of chemical spills and poor disposal practices of solid and liquid wastes pose a potential threat to any groundwater basin as well as to surface waters. Some may occur accidentally while others are part of cultural operations (sanitary landfills, liquid waste lagoons).

The accidental hazardous materials spills, particularly of organic solvents and motor fuels, from leaking underground storage tanks are of major concerns to groundwater supply and could begin to restrict management options.

As it can be deduced from the hydrogeologic makeup and operation of the groundwater basins, hazardous materials spills occurring in different areas of the basin surfaces can have different effects upon the groundwater, as contaminants are leached down to the groundwater or move and disperse within the basin.

PRESENT AND FUTURE BASIN UTILIZATION

At present about 50 percent of the total waters used in the basin is from groundwater in the Santa Clara Valley and 100 percent in Coyote Valley. The present annual drafts from Santa Clara Valley Basin and Coyote Valley Basins are about 150,000 acre-feet and about 12,000 acre-feet, respectively. As the basins represent an enormous storage unit, many times larger than the combined local surface storage facilities, a large capacity natural filtration unit and a vast natural distribution system, how they are utilized and operated plays an important role in the economy of the area and will continue to do so in the future. The District continues to exert concentrated efforts in the management of the basins.

All future plans of the District in providing for adequate water supply to maintain the economy of the area include the groundwater basins as an integral part of their programs (Santa Clara Valley Water District, December 1975). Even with a projected increase in importation of water supplies, imported water will not totally meet the projected needs of the area. The increase in importation will in fact increase the importance of the groundwater basins as a storage unit, as the reliability of imported supplies may vary, depending upon supplies available and litigated priorities. The District's water supply planning studies for Coyote Valley project continued 100 percent groundwater use to the year 2020 (Santa Clara Valley Water District, 1983).

In the event of a prolonged drought, which would affect not only this local area but also the source areas of imported waters, the groundwater basins will represent the sole source of significant supplies during such a period by virtue of their enormous storage capacities. The same will apply in case of interruption of imported water services caused by any major damages to the importation facilities, either by natural disaster or accident.

SUMMARY OF SIGNIFICANT FINDINGS RELATED TO THE STUDY

1. The groundwater basins can generally be divided into practical hydrogeologic units as based upon the character of the aquifer-aquitard systems and upon the occurrence, recharge and movement of groundwater. These units in Santa Clara Valley were noted as the "Forebay," "Upper Aquifer Zone" and the "Lower Aquifer Zone." Coyote Valley is essentially one unconfined unit analogous to the forebay unit of Santa Clara Valley.

2. Any accidental hazardous materials spill occurring in the forebay, the principal recharge unit of the Santa Clara Valley basin, can be leached directly to the groundwater which occurs unconfined for practical purposes. Depth to groundwater over much of the forebay is relatively shallow, within 50 feet of the surface except in certain areas along the northwestern forebay area and in the area just down gradient from Edenvale Gap, south of downtown San Jose.

   Once contaminants enter the groundwater in the forebay, they will migrate freely as stratification is usually weak and the permeabilities are relatively high. If left unchecked, they have the potential to migrate laterally toward the basin interior into both the upper aquifer zone and confined lower aquifer zone, just as recharging waters do.

3. In Santa Clara Valley as the depth of the upper aquifer zone encompasses aquifers to depths less than 150 feet within the basin interior, this zone is decreasing in its importance as a water supply unit. A vast majority of the local spills of highly toxic organic solvents have occurred overlying the upper aquifer zone. Depths to groundwater in this zone is relatively shallow, within 30 feet of the surface and at times to levels of the bottom of underground storage tanks. Much of the area within this zone is covered by a clay cap of varying thickness, usually about 20 feet. Semi-perched groundwater often occurs within the clay

cap. As it was noted in the saltwater intrusion studies and in the investigative studies of the various spills cases, the clay cap and intervening aquitards that separate the individual aquifers within the upper aquifer zone are known to be leaky. Hence, contaminant spills that have occurred over the upper aquifer zone quickly found their way to the various aquifers within the zone.

A relatively small annual volume of water continues to be pumped from this zone, principally for domestic or agricultural purposes. Some of the deep wells are perforated in both the upper and lower aquifer zones. Wells tapping the upper aquifer zone in nearby areas of the spills have become contaminated. Alternative source of water had to be sought in these instances that involved domestic supplies. The alternative source used was public water supplies which taps only the lower aquifer zone or which receive water from imported sources.

4. The lower aquifer zone represents the principal pumping source of groundwater within the interior portion of Santa Clara Valley. As it was also noted in the saltwater intrusion studies, the lower aquifer zone is separated from the upper aquifer zone by an extensive and thick aquitard which is essentially impermeable. -This aquitard has----- protected the lower aquifer zone from saltwater contamination and organic solvent spills that occurred in portions of the overlying upper aquifer zone.

5. However,the separating major aquitard could be bypassed by contaminants occurring in the lateral forebay or, as also noted in the saltwater intrusion studies, its integrity can be compromised by water wells perforated or open in both the upper and lower aquifer zones. Wells that are gravel packed through both zones can also effect interaquifer transfers. Figure 10 diagrammatically depicts how the lower aquifer zone may potentially become contaminated through such interaquifer transfers through wells. Although judicious enforcement of well standards in the construction and destruction of abandoned wells plays an important role in minimizing interaquifer transfers, it may not be possible to locate all the potential culprit wells which were drilled before the ordinance. After urbanizing of a large part of the Valley floor, a large number of the thousands of abandoned wells, most of which are suspected to be improperly sealed, may now occur beneath buildings, roads and parking lots. A judicious effort is being made by the District to locate and seal as many of the abandoned wells as possible to minimize interaquifer flows to the extent possible.

6. Due to the sensitivity of the basin to accidental or incidental contamination, the protection of the basin must rely on prevention through the enactment of zoning and ordinances. Recently adopted local and State ordinance that augments existing laws will play an important role in prevention of contamination.

7. In the incidence of spills cases, the priority of immediacy of action, recognizing the available resources in manpower to deal with the problems, would have to be given to spills that occur within the unprotected forebay or cases which occur in an area of a high density of existing or abandoned water wells.

8. As the groundwater basins represent a significant water supply feature to the economy and welfare of the area and will continue to play an important role in the future, the protection of the basins is of paramount importance. Existing efforts to prevent contamination and to implement judiciously existing protective ordinances would have to be maintained on a broad based approach.

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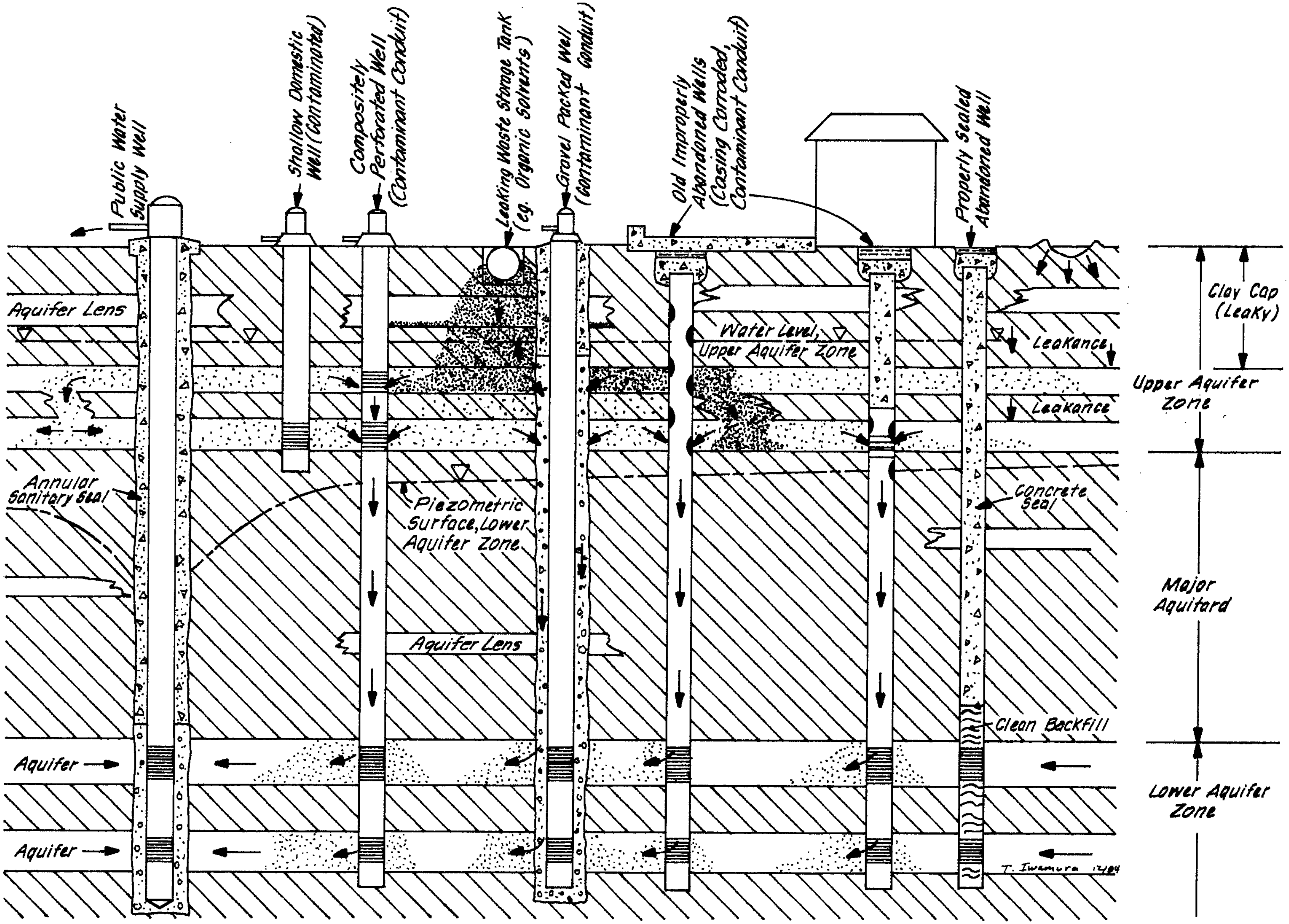
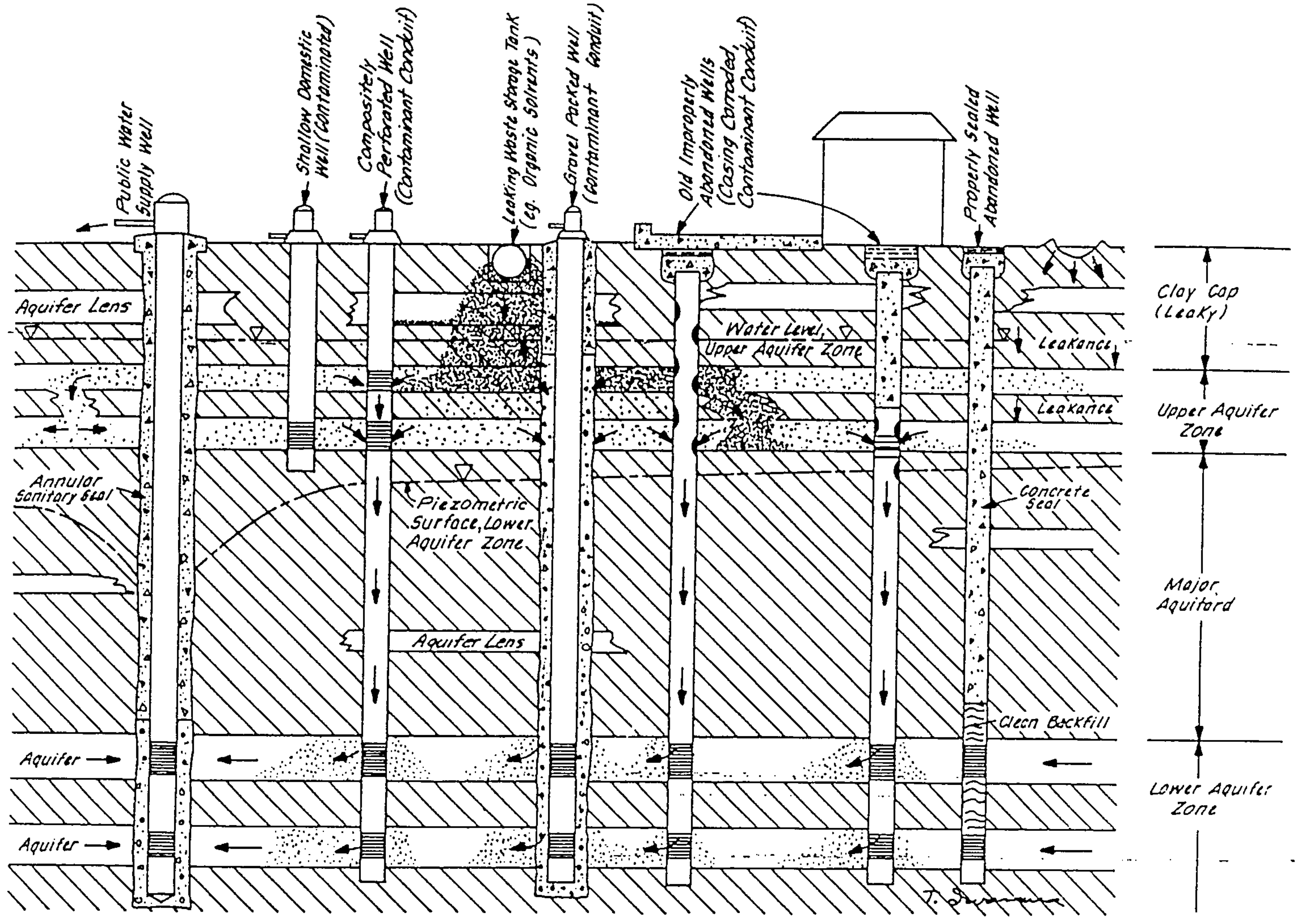

Public Water Supply Well
Shallow Domestic Well (Contaminated)
Compositely Perforated Well (Contaminant Conduit)
Leaking Waste Storage Tank (eg. Organic Solvents)
Gravel Packed Well (Contaminant Conduit)
Old Improperly Abandoned Wells (Casing Corroded, Contaminant Conduit)
Properly Sealed Abandoned Well
Clay Cap (Leaky)
Aquifer Lens
Water Level, Upper Aquifer Zone
Leakance
Leakance
Upper Aquifer Zone
Annular Sanitary Seal
Piezometric Surface, Lower Aquifer Zone
Concrete Seal
Major Aquitard
Aquifer Lens
Clean Backfill
Aquifer
Lower Aquifer Zone
Aquifer
T. Iwamura 12/84

Note : Intensity of dot pattern denotes relative contaminant concentration

FIGURE 3. DIAGRAMMATIC PROFILE, POTENTIAL INTERAQUIFER CONNECTIONS THROUGH WELLS, CONFINED BASIN INTERIOR AREA


Public Water Supply Well
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Aquifer Lens
Water Level, Upper Aquifer Zone
Leakance
Leakance
Annular Sanitary Seal
Piezometric Surface, Lower Aquifer Zone
Concrete Seal
Aquifer Lens
Clean Backfill
Aquifer
Aquifer
Clay Cap (Leaky)
Upper Aquifer Zone
Major Aquitard
Lower Aquifer Zone
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Note : Intensity of dot pattern denotes relative contaminant concentration

Figure 10. Diagramatic Profile, Potential Interaquifer Connections Through Wells; Confined Basin Interior area.

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